THE HOT STAR NEWSLETTER

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An electronic publication dedicated to A, B, O, Of, LBV and Wolf-Rayet stars and related phenomena in galaxies

ed. Philippe Eenens
eenens@tonali.inaoep.mx

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http://webhead.com/∼sergio/hot/
http://www.inaoep.mx/∼eenens/hot/

From the editor

With this issue, the Hot Star Newsletter reaches its 200th abstract of papers to appear in refereed journals. Noteworthy are a few papers on Wolf-Rayet stars in nearby galaxies as well as on Wolf-Rayet galaxies.

To assist us in our Wolf-Rayet research, Karel A. van der Hucht provides us with an updated version of the bibliography of WR literature. Updates are forseen every three months. The TeX files covering the last six years are available from the author `K.vanderHucht@sron.ruu.nl` or on the Web at URLs:

`http://webhead.com/∼sergio/hot/bibli/`
`http://www.inaoep.mx/∼eenens/hot/bibli/`

Contents of this newsletter

News

Spectroscopic Data on the WWW

Spectroscopists can rejoice in a huge amount of data just put on the World Wide Web by the National Institute of Standards and Technology (NIST). Besides the 1986 CODATA recommended values of the fundamental physical constants, you can now find a wealth of atomic and molecular spectroscopic data at `http://physics.nist.gov/PhysRefData/contents.html` including:

- Bibliographic Database on Atomic Transition Probabilities: An interactive database with references on atomic transition probabilities (oscillator strengths, line strengths, and radiative lifetimes). Both theoretical and experimental papers are listed. (Searchable)
- Atomic Spectroscopic Database: Includes most of the existing critically evaluated NIST data on atomic energy levels, transition probabilities, and wavelengths that are reasonably up-to-date. This interactive database has energy level data for over 500 spectra, transition probabilities for Sc through Ni, and wavelength data for spectra of several elements. (Searchable)
- Atlas of the Spectrum of a Platinum/Neon Hollow-Cathode Reference Lamp in the Region 1130-4330 : An atlas of the spectrum is given, with the spectral lines marked and their intensities, wavelengths, and classifications listed. (Searchable)
- Wavenumber Calibration Tables From Heterodyne Frequency Measurements: An atlas of molecular spectra and associated tables of wavenumbers for the calibration of infrared spectrometers. (Searchable by wavelength region)
- Bibliography of Photon Total Cross Section (Attenuation Coefficient) Measurements 10 eV to 13.5 GeV, 1907-1993: A bibliography of papers reporting absolute measurements of photon (XUV, x-ray, gamma-ray, bremsstrahlung) total interaction cross sections or attenuation coefficients

Accepted Papers

MWC 314 – A High-Luminosity Peculiar Be Star

Anatoly S. Miroshnichenko

Central Astronomical (Pulkovo) Observatory of the Russian Academy of Sciences, 196140 Saint–Petersburg, Russia

New broad-band multicolor ($UBVRIJHK$) photometry and optical spectroscopy of an emission-line star MWC 314 = BD+14°3887 as well as a study of its ultraviolet spectrum are reported. It is shown that the star exhibits photometric variability (Δ V $\sim 0.^m3$) with a quasi-regular component. Main parameters of the star and its envelope are estimated from both the spectral energy distribution and Balmer emission line analysis. It is concluded that MWC 314 is a highly reddened ($A_V = 5.^m7$) supergiant with strong slow stellar wind. The stellar parameters are: log $L/L_\odot \sim 6.2$, $T_* \sim 30\,000$ K, $R_* \sim 50\ R_\odot$, which yield an initial mass of about 80 $M_\odot$. The stellar wind has quite a low terminal

velocity ($v_\infty \sim 500$ km s^{-1}), a high mass loss rate ($\dot{M} \sim 3\,10^{-5}$ M$_\odot$ yr^{-1}), and a density structure similar to that of P Cyg. There is no evidence for a dust shell in the vicinity of the object. A comparison of the object's parameters with those of LBVs and B[e] – supergiants is also presented. MWC 314 can be considered as a candidate LBV.

Accepted by A & A *For preprints, contact* anat@pulkovo.spb.su

The HI bubble surrounding the Wolf-Rayet star WR 149

C.E. Cappa[1,2], V.S. Niemela[2], U. Herbstmeier[3,4] and B. Koribalski[5]

[1] Instituto Argentino de Radioastronomía, CC5, 1894 Villa Elisa, Argentina

[2] Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque, 1900 La Plata, Argentina

[3] Max-Planck Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

[4] Radioastronomisches Institut der Universität Bonn, Auf dem Hugel 71, D-53121 Bonn, Germany

[5] Max-Planck Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

Neutral hydrogen 21-cm observations obtained with the 100-m Effelsberg telescope have disclosed a HI bubble surrounding the WN6-7 star WR 149, located in the far side of the Perseus spiral arm. With a radius of 57 pc and an expansion velocity of about 10 km s^{-1}, this new bubble appears similar to those previously found around other Wolf-Rayet stars. Since stars of WN6-7 spectral sub-type are often found in open clusters and associations, we suggest that the observed HI bubble may be related to an undetected OB association. A second HI void in the neighbourhood is briefly discussed.

Accepted by A&A *For preprints, contact* ccappa@fcaglp.fcaglp.unlp.edu.ar
Also available via anonymous ftp from 163.10.4.47 in pub/virpi/wr149.ps

Boron in main sequence B stars: a critical test for rotational mixing

Jens Fliegner[1], Norbert Langer[1], and Kim A. Venn[1,2]

[1] Max-Planck-Institut für Astrophysik, D-85740 Garching, Germany

[2] Univ.-Sternwarte München, Scheinerstr. 1, D-81679 München, Germany

Recently, Venn et al. (1996) showed that the strength of the UV line of B II in five Galactic main sequence B stars — i.e. in 100% of their sample — can only be understood if the boron abundance in these stars is considerably less than the meteoritic/solar boron abundance of $\log \epsilon(B) = 2.88$ (Anders & Grevesse 1989). Furthermore, a spread of the boron abundances in these otherwise similar stars appears to indicate that the boron depletion occurs during the main sequence evolution.

We analyze the results of recent stellar evolution calculations (Fliegner & Langer 1996) for stars of 10 and $15 M_\odot$ which include the effects of rotation on the stellar structure as well as various mixing processes triggered thereby, and an appropriate nuclear network to follow the evolution of all elements from hydrogen to silicon. Mass loss, at the observed and predicted rates for B stars, is found to have little effect on the boron depletion. The rotating models predict a distinct correlation between nitrogen enhancement and boron depletion, as the thermonuclear destruction of boron occurs in the outer stellar envelope but the synthesis of nitrogen occurs in the deep interior of the stars. Thus, the N/B ratio reflects the efficiency of the mixing processes in quite different stellar layers. The qualitative agreement of this correlation with the observed boron and nitrogen abundances of main sequence B

stars provides the strongest evidence for rotational mixing acting in massive main sequence stars so far.

Accepted as Letter to the Editor by A & A *Preprints* are available as file /pub/ntl/boron.ps on machine 130.183.83.33. ; or contact N. Langer: `ntl@ipp-garching.mpg.de`

Two nitrogen rich main sequence B-stars in the SMC cluster, NGC 330

D.J. Lennon[1], P.L. Dufton[2], P.A. Mazzali[3], F. Pasian[3], G. Marconi[4]

[1] Institutit für Astronomie und Astrophysik der Universität München, Scheinerstrasse 1, D-81679 München, Germany

[2] The Department of Pure and Applied Physics, The Queen's University of Belfast, Belfast BT7 1NN, N. Ireland

[3] Osservatorio Astronomico di Trieste, Via G.B. Tiepolo 11, I-34131 Trieste, Italy

[4] Osservatorio Astronomico, Viale dell'Osservatorio, I-00040 Monte Porzio Catone (Rome), Italy

High resolution spectra of two narrow lined main-sequence B-type stars in the SMC cluster NGC330 are analysed using LTE methods to obtain their chemical compositions relative to SMC and galactic field B-stars. It is found that these stars, designated A01 and B04, have parameters ($\{T_{eff}$, $\log g\}$) of {26 000, 3.8} and {23 000, 3.6} respectively and, surprisingly, nitrogen abundances approximately 0.8 dex higher than other SMC main-sequence B-stars. There is also marginal evidence for moderate deficiencies of both oxygen and silicon consistent with the previously reported low metallicity of this cluster. Since supergiants in the cluster do not exhibit such a large nitrogen enrichment it is argued that A01 and B04 have had their surface chemical compositions modified either as the result of binary mass transfer or due to rotationally induced turbulent diffusion. For both scenarios the absence of a complementary carbon deficiency is surprising. These findings, combined with previous observations of the most lumninous main-sequence stars in the cluster, imply that the upper main-sequence of the cluster is difficult to understand in terms of standard stellar evolution models.

Accepted by A & A *For preprints, contact* `djl@usm.uni-muenchen.de`

The Dynamics of Superbubbles in the Large Magellanic Cloud

M. S. Oey[1,2]

[1] Steward Observatory, University of Arizona, Tucson, AZ 85721

[2] Present address: Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, United Kingdom

Based on the stellar populations observed within this sample of LMC superbubbles, I use a numerical version of the standard, pressure-driven bubble model to investigate the shell dynamics. The results fall into two distinct categories corresponding to a subset of objects for which the observed expansion velocity is too large for the observed shell radius ("high-velocity" superbubbles), and a subset of objects which appears more dynamically consistent with the model ("low-velocity superbubbles"). Both subsets of objects imply an overestimate in the shell growth rate equivalent to an overestimate in input power by up to an order of magnitude. The high-velocity objects exhibit X-ray evidence of supernova activity, suggesting that the dynamical discrepancy is due to acceleration by SNR impacts.

Accepted by ApJ *For preprints, contact* `oey@ast.cam.ac.uk`
Postscript version available at http://www.ast.cam.ac.uk/∼oey/oeypubs.html.

Spectroscopic Binary Orbits from Ultraviolet Radial Velocities. Paper 19: μ^1 Scorpii (HD 151890)

D. J. Stickland[1], J. Sahade[2] and H. Henrichs[3]

[1] Rutherford Appleton Laboratory, Chilton

[2] Observatorio Astronomico, La Plata

[3] Astronomical Institute, Amsterdam

IUE SWP high-resolution observations have been used to redetermine the orbital elements of the B1.5V + B6V: spectroscopic binary μ^1 Sco. The results give $m \sin^3 i$ for the two components as 5.9 and 3.8 $M_\odot$ respectively, significantly less than the previous determination by Struve.

Accepted by The Observatory

Preprints from ds@astro1.bnsc.rl.ac.uk

Spectroscopic Binary Orbits from Ultraviolet Radial Velocities. Paper 20: HD 149404

D. J. Stickland[1] and R. H. Koch[2]

[1] Rutherford Appleton Laboratory, Chilton

[2] University of Pennsylvania, Philadelphia

IUE SWP high-resolution observations have been used to determine the orbital elements of the O8.5I + O7III(f) spectroscopic binary. The low velocity amplitudes of the components made measurements difficult and the binary appears to exhibit the "Struve-Sahade Effect" in which the spectrum of the secondary is strengthened during its approach to the observer (at least some of the time!). The present results broadly confirm the findings of Massey & Conti and give $m \sin^3 i$ 1.7 and 2.6 $M_\odot$ for the components of this low-inclination system.

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The winds of hot stars in external galaxies. III. *HST* UV spectroscopy of O and B supergiants in M31 and M33

Luciana Bianchi[1,2], J.B. Hutchings[3] and Philip Massey[4]

[1] Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218, USA

[2] Osservatorio Astronomico di Torino, I-10025 Pino Torinese (TO), Italy

[3] Dominion Astrophys.Observatory, 5071 W.Saanich rd., Victoria, B.C., Canada, V8X 4M6

[4] Kitt Peak National Observatory, National Optical Astronomy Observatories, P.O. Box 26732, Tucson, AZ85726-6732

HST Faint Object Spectrograph (FOS) UV (1200-3300 Å) spectra of nine late-O and early-B supergiants in M31, and one B1.5 supergiant in M33, are presented. The morphologies of the UV line spectra are discussed, and compared with those of Galactic and Magellanic Cloud stars of similar optical spectral type. The UV spectral signatures of the M31 and M33 supergiants are similar to the comparison stars, in general, with some differences due to metallicity effects. Chemical peculiarities are seen in three M31 supergiants.

The strength of the P Cygni profiles in the wind lines indicates abundances similar to the LMC in M33, and similar to our Galaxy in M31. Wind velocities in M31 supergiants are comparable to Galactic

values. Narrow absorption components at high velocity are seen in the wind of the M33 supergiant, revealing clumpiness in the wind.

Accepted by the Astronomical J *Preprints from* `Bianchi@stsci.edu`

Projected Rotational Velocities of O-Type Stars

Laura R. Penny[1]

[1] Center for High Angular Resolution Astronomy, Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30303 U.S.A.

I present an homogeneous set of projected rotational velocities for 177 O-stars based upon *IUE* high dispersion spectra of the UV photospheric lines. The line widths are estimated by cross-correlating each spectrum with the spectrum of a narrow-lined O-star (HD 34078), and the widths of the cross-correlation functions are transformed to projected rotational velocity using a calibration based on the $V \sin i$ data of Conti & Ebbets (1977). The sample includes 120 stars in common with those of Conti & Ebbets plus 57 new targets. I identify 10 stars as potential new double-lined spectroscopic binaries and 20 rapidly rotating stars as possible new line profile variables (displaying bumpy profiles associated with nonradial pulsation). There are few narrow-lined stars among the more massive and more evolved O stars which suggests that macroturbulent broadening is important in such objects. The fast est rotators are found among the lower mass O stars, which may reflect a loss of angular momentum through stellar winds among higher mass stars.

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Hubble Space Telescope Ultraviolet Spectroscopy of NGC 1741: A Nearby Template for Distant Energetic Starbursts

Peter S. Conti[1], **Claus Leitherer**[2] **and William D. Vacca**[3]

[1] Joint Institute for Laboratory Astrophysics, Campus Box 440, University of Colorado, Boulder, CO 80309

[2] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

[3] Institute for Astronomy, 2680 Woodlawn Dr., Honolulu, HI 96822

We have obtained a Hubble Space Telescope ultraviolet image and spectrum of the nearby Wolf-Rayet galaxy NGC 1741. The spatial morphology from the Faint Object Camera image is dominated by two main starburst centers, each being about 100 times as luminous as 30 Doradus. Both starburst centers are composed of several intense knots of recent star formation. A Goddard High Resolution Spectrograph spectrum of a portion of the southern starburst center is consistent with a population of young stars following a Salpeter IMF for masses above $\sim$15 $M_{\odot}$(lower mass stars may also be present) and extending up to $\sim$100 $M_{\odot}$about 104 O-type stars are inferred from the UV luminosity. Numerous strong interstellar lines are detected. Although not resolved, their strength suggests that they are formed in individual bubbles and shells with velocities up to a few hundred km s-1. The red wing of the Ly alpha absorption profile indicates the presence of several neutral hydrogen components, one in our own Galaxy and the others at or close to the distance of NGC 1741. Overall, the stellar and interstellar line spectrum, as well as the continuum shape of NGC 1741, strongly resembles star-forming galaxies recently discovered at high redshift.

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Submitted Papers

The Wolf-Rayet Binary V444 Cygni under the Spectroscopic Microscope. II. Physical Parameters of the Wolf-Rayet Wind and the Zone of Wind Collision

S.V. Marchenko[1], A.F.J. Moffat[1], P.R.J. Eenens[2], O. Cardona[2], J. Echevarria[3] & Y.Hervieux[1]

[1] Département de physique, Université de Montréal, C.P. 6128, Succursale Centre-Ville, Montréal, Québec, H3C 3J7, Canada, and Observatoire du mont Mégantic. E-mail: sergey,moffat,hervieux@astro.umontreal.ca

[2] Instituto Nacional de Astrofísica, Optica y Electrónica, Apdos. Postales 216 y 51, Puebla 72000, Pue., México.

[3] Instituto de Astronomía, Apartado Postal 877, C.P. 22860, Ensenada, México.

New, extensive, high signal-to-noise, phase-dependent optical spectroscopy, along with simultaneous narrow-band continuum photometry, leads to restrictions on the electron temperature and density in the wind close to the Wolf-Rayet component of the eclipsing binary V444 Cygni (WN5 + O6 V-III). We extend our previous discussion of the wind-wind collision effects on HeI lines to HeII lines. We find that: (1) the wind-wind collision zone is detached from the surface of the O star; (2) the radiation field of the O star does not inhibit the *initial* acceleration of the W-R wind; however, it does brake the flow just prior to entrance into the collision zone; (3) the shocked gas experiences rapid, $t_{cool} \lesssim (2-4) \times 10^4$ sec, and profound cooling via radiative losses, leading to high compression of the post-shock gas.

Submitted to ApJ *Preprints from* sergey@astro.umontreal.ca *or by anonymous ftp to* ftp.astro.umontreal.ca (132.204.60.20), cd /incoming/sergey/part2

Variations of the stellar wind in early-B hypergiants

Th. Rivinius[1], O. Stahl[1], B. Wolf[1], A.Kaufer[1], Th. Gäng[1,2], C.A. Gummersbach[1], I. Jankovics[3], J. Kovács[3], H. Mandel[1], J. Peitz[1], Th. Szeifert[1], H.J.G.L.M. Lamers[2,4,5]

[1] Landessternwarte Königstuhl, D-69117, Heidelberg, Germany

[2] STScI, Homewood Campus, 3700 San Martin Drive, Baltimore MD 21218, USA

[3] Gothard Astrophysical Observatory, H-9707 Szombathely, Hungary

[4] SRON Laboratory for Space Research, Sorbonnelaan 2, NL-3584 CA Utrecht, The Netherlands

[5] Astronomical Institute, Princetoplein 5, NL-3584 CC Utrecht, The Netherlands

We have monitored the three early-B hypergiants ζ^1 Sco (HD152236), HD169454, and HD190603 with our fiber-linked echelle spectrograph with high dispersion and good coverage in time over periods of several months in several seasons. In the years 1990 to 1994 we covered the wavelength range from 4000 Å to 6740 Å and in 1995 from 3450 Å to 8620 Å, respectively. Typically one spectrum every one or two nights of each object was taken. We found the P Cygni-type profiles of all objects to be variable, both in the emission and in the absorption part. Blue-shifted variable absorption features can be seen in many lines. These features are seen particularly clear in the FeIII$\lambda\lambda$5127, 5156 lines, where they

can be traced from photospheric velocities to approximately $-200\,\mathrm{km\,s^{-1}}$. In the cores of photospheric lines we find radial-velocity variations of about $20\,\mathrm{km\,s^{-1}}$on time scales of weeks and showing a time delay and a velocity shift between different lines. We interpret this as the propagation of disturbances through the innermost layers of the wind. These perturbations originate in the photosphere or the sub-photosphere. The variability of the discrete absorption components (DACs) of the P Cygni-type profiles can be modeled assuming density perturbations of the order of 10% at the base of the wind. The outward propagation of these perturbations, with a velocity law ($\beta = 2.5$) that is slower than that of the ambient wind ($\beta = 1.5$), can explain the observed variations.

The absorption lines show cycles of pulsation-like radial-velocity variations, with a period of about 12 days. These variations last a few cycles before becoming irregular. By integrating these variations we expect the radius variations to be of the order of 10% of the stellar radius. These variations are connected to the emission variability. The photometric data indicate a possible radial pulsation with this amplitude.

The mass-loss rates of the stars, derived from the Balmer-emission components, is between 2.7 and $6.3 \cdot 10^{-6}\,\mathrm{M_\odot yr^{-1}}$. The terminal velocities are between 370 and $515\,\mathrm{km\,s^{-1}}$. The ratio $v_\infty/v_{\mathrm{esc}}$ is between 1.0 and 1.4, which shows that the stars are on the "low side" of the bi-stability jump for the winds of supergiants found recently by Lamers et al. (1995).

Submitted to A & A *Preprints from* `T.Rivinius@lsw.uni-heidelberg.de`
or by anonymous ftp: `ftp://ftp.lsw.uni-heidelberg.de/incoming/rivi/BHyper.ps.gz`
or on the Web: `http://www.lsw.uni-heidelberg.de/~triviniu/` (with some color plots)

An Atlas of OB Spectra from 1000Å to 1200Å

Nolan R. Walborn[1] **and Ralph C. Bohlin**[1]

[1] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, Maryland 21218

Copernicus low-resolution (0.2Å) observations of 16 O stars, 10 B stars (mostly supergiants), and one WN-A star with the highest data quality between 1000 and 1200Å are presented in the form of a classical spectral atlas. The purpose is to survey the systematic spectral-type/luminosity-class dependence of the line features, including those from the stellar winds, in this relatively less studied wavelength range. Perhaps the most important new contribution is the demonstration of the pronounced luminosity effect in the S IV $\lambda\lambda$1063, 1073 wind profiles, identical to those previously recognized in Si IV $\lambda\lambda$1394, 1403 and C III λ1176, which share essentially the same ionization potential. The stellar-wind effects in O VI $\lambda\lambda$1032, 1038; P V $\lambda\lambda$1118, 1128; Si IV $\lambda\lambda$1122, 1128; and C III λ1176 are also described. Attention is redrawn to the unidentified feature at 1099Å, which is one of the strongest absorption lines in this range of mid-O through early-B spectra. The atlas will facilitate interpretations of recent *Hopkins Ultraviolet Telescope* and future *Far Ultraviolet Spectroscopic Explorer* observations in this wavelength range, as well as sharpen the stellar-wind phenomenology for astrophysical analysis.

Submitted to PASP *For preprints, contact* `walborn@stsci.edu`

Hubble Space Telescope Ultraviolet Imaging and Spectroscopy of the Bright Starburst in the Wolf-Rayet Galaxy NGC 4214

Claus Leitherer [1], **William D. Vacca** [2], **Peter S. Conti** [3],

Alexei V. Filippenko [4], **Carmelle Robert** [5], and **Wallace L. W. Sargent** [6]

[1] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218; e-mail: leitherer@stsci.edu

[2] Institute for Astronomy, 2680 Woodlawn Drive, Honolulu, HI 96822; e-mail: vacca@athena.ifa.hawaii.edu

[3] JILA, University of Colorado, Boulder, CO 80309-0440; e-mail: pconti@jila.colorado.edu

[4] Department of Astronomy, University of California, Berkeley, CA 94720-3411; e-mail: alex@astro.berkeley.edu

[5] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218; currently at University of Laval, Dept. of Physics, Quebec, G1K 7P4 Canada; e-mail: crobert@phy.ulaval.ca

[6] Astronomy Dept., 105-24, California Institute of Technology, Pasadena, CA 91125; e-mail: wws@deimos.caltech.edu

We have obtained an *HST Faint Object Camera* ultraviolet image and *Faint Object Spectrograph* ultraviolet spectra of the central starburst region in the nearby amorphous galaxy NGC 4214. The ultraviolet image reveals a bright, compact, starburst knot surrounded by more than 200 fainter point-like sources. Spectral synthesis modeling of the ultraviolet spectrum of the central starburst knot suggests the stellar population has an age of 4 – 5 Myr. The extinction–corrected ultraviolet flux implies that hundreds of O type stars are contained within a diameter of at most 5 pc. The inferred number of Wolf–Rayet (W-R) stars implies that the star formation episode occurred in a short duration burst. The starburst knot contains roughly twice the number of O stars as in a similar size region centered on R136a in 30 Doradus but it is slightly older. The knot in NGC 4214 is comparable in size and luminosity to the starburst knots identified in the core of the W-R galaxy He 2-10 and to the super star clusters found in other star–forming galaxies. The number of Lyman continuum photons inferred from Hα measurements is at least a factor 4 smaller than that predicted from the observed numbers of hot stars; this starburst knot is thus "density bounded" to ionizing radiation. The fainter point-like sources seen in the ultraviolet image are probably individual hot stars, or small groups of stars. The ultraviolet luminosity function of these objects is similar to that found for stars within 30 Doradus. **Submitted to Ap J** *Preprints from* `leitherer@stsci.edu`

Sudden Radiative Braking in Colliding Hot-Star Winds

K. G. Gayley, S. P. Owocki, and S. R. Cranmer[1]

[1] Bartol Research Inst., 217 Sharp Lab, Newark, DE 19716

Hot, massive stars have strong stellar winds, and in hot-star binaries these winds can undergo violent collision. Because such winds are thought to be radiatively driven, radiative forces may also play an important role in moderating the wind collision. However, previous studies have been limited to considering how radiatve forces may inhibit the *initial acceleration* of the companion stellar wind. In this paper we analyze the role of an even stronger *radiative braking* effect, whereby the primary wind is rather suddenly decelerated by the radiative momentum flux it encounters as it approaches a bright companion.

We further show that the braking location and velocity law along the line of centers between the stars can be approximated analytically using a simple one-dimensional analysis. The results of this analysis agree well with a detailed two-dimensional hydrodynamical simulation of the wind collision in the WR+O binary V444 Cygni. The results demonstrate that, for reasonable values of the line-scattering parameters, radiative braking can significantly alter the bow-shock geometry and reduce the strength of the wind collision.

We then apply the derived analytic theory to a set of 14 hot-star binary systems, and conclude that radiative braking is likely to be of widespread importance for wind-wind collisions in WR+O binaries

with close to medium separation, $D \lesssim 100 R_\odot$. It may also be important in other types of hot-star binaries that exhibit a large imbalance between the component wind strengths.

Submitted to ApJ *Preprints from* gayley@brivs2.bartol.udel.edu

The nature of the bright subdwarf HD 49798 and its X-ray pulsating companion

B.C. Bisscheroux[1], O.R. Pols[2], P. Kahabka[1,3], T. Belloni[1,3], E.P.J. van den Heuvel[1,3]

[1] Astronomical Institute 'Anton Pannekoek', University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

[2] Astronomical Institute, Madingly Road, Cambrdige, CB3 0HA, United Kingdom

[3] Center for High Energy Astrophysics, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

An analysis of the observed properties of the sub-dwarf O6 close binary system HD 49798 and its 13.18 s ultrasoft X-ray pulsating companion (WGA J0648.0-4418) is presented. On evolutionary grounds we show that the subdwarf must have a degenerate CO core and is in the phase of shell helium burning, which explains its high luminosity. The subdwarf, which probably has a mass between $0.7 - 1.3\,\mathrm{M}_\odot$, is the descendant of a massive asymptotic giant branch star that lost its hydrogen-rich outer layers in a common-envelope event. We show that all observations are consistent with the X-ray source being a weakly magnetized massive white dwarf which is accreting matter from the wind of its subdwarf companion. We exclude a neutron star companion on the ground of (1) the ultrasoft spectrum of the X-ray source; (2) the very close resemblance of the X-ray spectrum and luminosity with that of the soft intermediate polars; (3) the relative closeness of HD 49798, which implies a Galactic birthrate of such systems that is much larger than that of binary pulsars with a massive white dwarf companion, the natural descendants of systems like HD 49798 if the pulsar in this system were a neutron star.

Submitted to A&A *Preprints from* bartb@astro.uva.nl

Jet-like structures in β Lyr Results of optical interferometry, spectroscopy and photometry

P. Harmanec[1], F. Morand[2], D. Bonneau[2], Y. Jiang[3], S. Yang[4], E.F. Guinan[5], D.S. Hall[6], D. Mourard[2], P. Hadrava[1], H. Božić[7], C. Sterken[8], I. Tallon-Bosc[9], G.A.H. Walker[3], G.P. McCook[5], F. Vakili[2], Ph. Stee[2], J.M. Le Contel[10]

[1] Astronomical Institute, Academy of Sciences of the Czech Republic, 251 65 Ondřejov, Czech Republic

[2] Observatoire de la Côte d'Azur, Département FRESNEL, CNRS URA 1361, St Vallier de Thiey, France

[3] Department of Geophysics and Astronomy, University of British Columbia, 129-2219 Main Mall, Vancouver, B.C., V6T 1Z4 Canada

[4] Department of Physics and Astronomy, University of Victoria, P.O. Box 1700, Victoria, B.C., V8W 2V2 Canada

[5] Department of Astronomy and Astrophysics, Villanova University, Villanova, PA 19085, USA

[6] The Arthur J. Dyer Observatory, Vanderbilt University, Box 1803, Nashville, Tennessee 37235, USA

[7] Hvar Observatory, Faculty of Geodesy, Zagreb University, Kačićeva 26, 41000 Zagreb, Croatia

[8] Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium

[9] U.M.R CNRS 142, Observatoire de Lyon, 9 avenue Charles Andre, F-69561 Saint-Genis Laval Cedex

[10] Observatoire de la Côte d'Azur, Département FRESNEL, CNRS URA 1361, B.P. 229, 06034 Nice-Cedex 04, France

A preliminary analysis of an extensive collection of interferometric, spectroscopic and photometric observations of the bright Be star β Lyr lead to the following main conclusions:

(1) The bulk of the Hα and He I 6678 emission seems to originate in jets of material perpendicular to the orbital plane of the binary. The jets are associated with the more massive component of the binary (star 1) and probably emanate from the 'hot spot' in the disk, i.e. the region of interaction of the gas stream flowing from the Roche-lobe filling B6-8II component (star 2) toward star 1. Some contribution to the emission also comes from a region located between the two stars (the gas stream and the 'hot spot') and from the 'pseudoatmosphere' of the accretion disk around star 1.

(2) The 282-d cyclic variation of the light curve of β Lyr is confirmed on the basis of 2852 homogenized V-band observations covering an interval of 36 yrs. We find, however, that the amplitude and phase of these variations vary with the orbital phase: the long-term modulation of the light curve almost disappears near orbital phases $0^{\rm P}.25$ and $0^{\rm P}.50$ (elongation and secondary eclipse).

(3) Pronounced line-profile variations of the Hα and He I 6678 lines on a time scale *shorter than one orbital period* were clearly detected. They may be periodic, with a period near $4^{\rm d}.70$ – $4^{\rm d}.75$, and this periodicity may be related to the 282-d change via the orbital period.

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In Proceedings

Hot Luminous Stars in Nearby Galaxies

R.-P. Kudritzki[1,2], D.J. Lennon[1,2], S.M. Haser[1], J. Puls[1], A.W.A. Pauldrach[1], K. Venn[1,2], S.A. Voels[3]

[1] Universtitäts-Sternwarte München, D-81679 Munich, Germany

[2] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85740 Garching, Germany

[3] NASA-GSFC, Astrophysics Data Facility, Greenbelt, MD 20771, U.S.A

We discuss a new method for the determination of stellar distances using the dependence of the stellar mass-loss rate upon luminosity, the so-called *wind momentum – luminosity relationship*. We review some recent results on wind momentum rates and metallicities of O-stars and B-supergiants in the Magellanic Clouds and include some new results derived using HST data. Clear evidence for a metallicity effect in the Small Magellanic Cloud is found, the effect for the Large Magellanic Cloud being only moderate. We discuss the need to calibrate the relationship using supergiants in these galaxies so that the method may be applied to supergiants in more distant galaxies. The potential of this method with regard to both distance and metallicity determinations is illustrated by results for two supergiants in each of the galaxies M31 and M33. We also show new HST/WFPC2 images of massive O-stars in the Magellanic Clouds and, in combination with previous optical and HST/FOS spectra, suggest that these data constitute evidence that one of these stars, Sk$-67^{\rm o}$211, may have a mass of close to $200{\rm M}_\odot$.

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For preprints, contact `djl@usm.uni-muenchen.de`

Mass Loss from Stars

Henny J.G.L.M. Lamers[1] and Joseph P. Cassinelli[2]

[1] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
and Astronomical Institute and SRON Laboratory for Space Research, Utrecht, The Netherlands
[2] Astronomy Department, University of Wisconsin, 475 N Charterstreet, Madison, WI 53706, USA

We describe the methods for the determinations of mass loss from hot and cool stars. We discuss empirical mass loss rates and wind velocities and their dependence on the stellar parameters. We present a new formula for the calculation of mass loss rates from early type stars, based on empirical mass loss rates and predicted scaling laws.

To appear in: *From Stars to Galaxies: The Impact of Stellar Physics on Galaxy Evolution*, eds. C. Leitherer, U. Fritze-von Alvensleben, & J. Huchra, ASP Conf. Series Vol. 98. *preprints from* `hennyl@sron.ruu.nl`

Starburst Galaxies — Laboratories to Study Star Formation and Stellar Evolution

Claus Leitherer

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

Starburst galaxies are currently forming high-mass (and possibly also low-mass) stars at prodigious rates. Physical scales are highlighted for representative objects. If observed at sufficiently high spatial resolution, starbursts tend to break into individual clusters, suggesting brief bursts as the predominant star formation mode. Techniques to constrain the stellar content in starburst galaxies are reviewed and results for the initial mass function are critically examined. In agreement with results for massive-star-forming regions in the Local Group there is no strong evidence against a universal IMF, one possible exception being infrared-luminous galaxies. I point out areas in galaxy evolution modeling which are subject to uncertainty due to possible future revision of the input physics.

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Colliding Winds in Massive Binaries Involving Wolf-Rayet Stars

Anthony F.J. Moffat, Sergey V. Marchenko and Peter Bartzakos

Département de physique, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, QC, H3C 3J7, Canada, and Observatoire du mont Mégantic

Wolf-Rayet stars are notorious for their very strong, hot winds. Their presence in binary systems can therefore lead to strong wind collisions, that manifest themselves as well-defined, phase-dependent distortions of the spectral lines. Turning this around, profile variations can be used to determine properties of the wind collision, as well as the winds and even the orbit itself. We review the present situation regarding colliding winds for WR stars in WR + O, WR + WR, and WR + c systems.

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Preprints from `bartzako@astro.umontreal.ca` *or by anonymous ftp to* `ftp.astro.umontreal.ca, cd pub/article, get CWMB2.ps.gz`

Supernovae and their Progenitors

N. Langer[1], and S.E. Woosley[1,2]

[1] Max-Planck-Institut für Astrophysik, D–85740 Garching, Germany

[2] Astronomy Board of Studies, UC Santa Cruz, CA 95064, U.S.A.

The physics of supernova explosions and essential aspects of the progenitor evolution are discussed for both hydrodynamic (core collapse) and thermonuclear powered events. Sufficient information is given for non-specialists in the field to judge the reliability of the various predictions of current models and to apply the most recent results to studies of Galactic evolution.

To appear in: *From Stars to Galaxies: The Impact of Stellar Physics on Galaxy Evolution*, eds. C. Leitherer, U. Fritze-von Alvensleben, & J. Huchra, ASP Conf. Series Vol. 98, p. 220. *preprints* are available as file /pub/ntl/sn.ps on machine 130.183.83.33. ; or contact N. Langer: ntl@ipp-garching.mpg.de

Observations of Colliding Winds in O-Type Binaries

Douglas R. Gies[1]

[1] Center for High Angular Resolution Astronomy, Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30303 U.S.A.

Stellar winds will collide in a bow shock in close binary systems of O-type stars. The presence of this boundary will truncate the full spatial extent of the two individual winds, and thus the spectral lines formed in the wind will appear differently when viewed from different orientations. Here I discuss the orbital variations of the UV wind lines in a large sample of O-binaries that have been observed with the *International Ultraviolet Explorer Satellite (IUE)*. High density regions in the wind (near the photospheres and bow shock) will produce optical emission lines, and I describe the Hα emission properties of several systems. The physical characteristics of the component stars can now be better estimated through Doppler tomography, a numerical method to extract the individual primary and secondary spectra.

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Theses

The Peculiar Population of Helium Emission Stars at the Galactic Center

Peter Tamblyn[1]

[1] Steward Observatory, University of Arizona, Tucson, AZ 85721 USA

We show that extremely luminous, blue stars are present at the Galactic Center (GC) in numbers that are incompatible with normal stellar evolution. Helium 2.058 μm images with a spatial resolution of 1 arcsecond show that the helium emission is concentrated on point sources, most of which are bright in the infrared, indicating they are warm and very luminous. Comparison with Monte-Carlo stellar population models demonstrates that normal evolution is incapable of producing this population. Near-infrared spectroscopy at high angular and spectral resolutions has been obtained, along with spectra of an extensive suite of other warm, luminous stars. These spectra provide new constraints on the mass in the central 1/2 parsec and the spectral comparisons confirm the peculiarity of the GC stars. The brightest have few, if any, analogues known in the Galaxy. Constraints from space-based observations on the blue light associated with nuclear populations in nearby galaxies demonstrate that the GC is unique or in a time-dependent phase. We have examined and rejected a number of models expected to produce this density of luminous, blue stars in the central parsec. A possibility remains that they are recently formed massive stars with unusual evolution forced by close binary companions. This model predicts similar populations of peculiar stars only in other dense galactic nuclei which have undergone very recent star formation.

Dissertation completed under the direction of G. H. Rieke and Fulvio Melia *Available at* `http://www.as.arizona.edu/~ptamblyn` or from `ptamblyn@as.arizona.edu`

Quantitative Optical and Infrared Spectroscopy of Extreme Luminous Blue Supergiants

F. Najarro[1]

[1]Institut für Astronomie und Astrophysik der Universität München, Scheinerstr. 1, D-81679 München, Germany

The most dramatic progress in ground based astronomy in this decade has been made at long wavelengths in the electromagnetic spectrum, especially in the infrared. Revolutionary advances in detector technology together with refined methods to compensate for the disturbing influence of the earth's atmosphere in obtaining sharp images and the introduction of extremely efficient spectrographs has led to important new discoveries in almost all areas of astrophysical research. In stellar astrophysics, one of the major developments was the detection of a cluster He I 2.058μm emission lines stars in the Galactic center (Krabbe et al. 1991).

These new detections made clear that the theory of model atmospheres and radiative transfer was lagging behind and was unable to provide tools for diagnostic techniques to extract the astrophysical information present in the new near-infrared spectra.

The goal of this thesis is to improve the status of quantitative infrared spectroscopy and its consistency with optical studies, at least in the area related to the physics of hot luminous stars. Based on

spherically, extended model atmospheres that include the effects of stellar wind outflow, we present calculations of infrared (and optical) hydrogen and helium lines that allow the determination of stellar effective temperatures, helium abundances, mass-loss rates and velocity fields of hot stars with strong stellar winds.

In order to understand which processes govern the atmospheres of hot luminous stars we investigate, in detail, how stellar parameters such as luminosity, temperature, density, etc, influence both line profiles and continuous energy distributions. In a first application of our techniques we perform a detailed spectroscopic investigation of the Luminous Blue Variable P Cygni. The results are:

- The high mass-loss rate ($\dot{M}\approx 3.6\times10^{-5}\,M_\odot$) and flat velocity field ($\beta\sim4$) reveal a high density wind for the object.
- The ionization structure of hydrogen and helium undergoes a rapid change in the wind, so that both species recombine in the outer parts of the wind. This explains both the shape of the Hα profile and the observed radio variability of the object.
- The high helium abundance obtained (He/H$\approx$0.4 by number) indicates that this star is highly evolved. P Cygni is on its way to the red turn-over on the H-R diagram.
- Excellent agreement is obtained between our calculations and the observations. Continuum observations and observed main optical and near-infrared H and He I line profiles are well reproduced.
- Predicted IR profiles in the observing range (2.5–45 μm) of the Short Wavelenght Spectrograph (SWS) on board the infrared satellite ISO (which will be launched this Autumn) provide powerful diagnostic tools to constrain the stellar parameters of early type stars.

In a second application we make use of the experience obtained in analysing P Cygni and perform an investigation of the cluster of He I 2.058μm emission line stars in the Galactic center. This reveals:

- The broad emission lines of He I and H are caused by extremely strong stellar winds ($\dot{M}\sim5$ to $40\times10^{-5}\,M_\odot\,yr^{-1}$) with relatively small outflow velocities ($V_\infty\sim$ 300 to 1000 $km\,s^{-1}$).
- The effective temperatures range from 17,000 K to 30,000 K corresponding to stellar luminosities of 1 to $30\times10^5 L_\odot$.
- Strongly enhanced helium abundances ($N_{He}/N_H> .5$) are found.

These spectroscopic facts lead to the interpretation that:

- The He I emission line stars are evolved blue supergiants close to the evolutionary stage of Wolf-Rayet stars.
- The energetics and the radiation field in the central parsec of our Galaxy are dominated by a formation of the young stellar cluster of massive stars some 5×10^6 years ago.
- The velocity dispersion obtained from the radial velocities derived for these objects presents a good statistical evidence for a concentration of dark mass in the Galactic center.

Dissertation presented on July 21st 1995 *Available from* `paco@usm.uni-muenchen.de` *or by anonymous ftp to* `ftp.usm.uni-muenchen.de` *login as ftp, file is in* `pub/paco/thesis.ps.gz`

Meetings

Stellar Atmospheres: Theory and Observations

Ninth Predoctoral School of the European Astrophysics Doctoral Network

19 September 1996

Vrije Universiteit Brussel and the Royal Observatory, Belgium.

Subject. The School focusses on the basic physics of atmospheres, the observing techniques and presently used technologies, and on the analysis of observations.

Participants. The course is aimed at graduate students in the first or second year of their Ph.D. work. We require active participation on the part of the students and expect to bring together only the most motivated people. Participation is restricted to maximum 30 graduate students.

Organisation. Jean-Pierre De Greve,
Astronomy Group, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium.
Telephone: 32-2-629.34.98
Fax: 32-2-629.34.24
e-mail: jpdgreve@vnet3.vub.ac.be
World Wide Web page: http://www.vub.ac.be/STER/ster.html